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A UNITIZED BRUSH GRADER-SIZER FOR APPLES

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PREFACE

The unitized brush grader-sizer reported on here is a product of the U.S. Department of Agriculture's program for designing, developing, and testing new and improved methods and equipment for preparing horticultural products for market. The objective was an item of equipment with which apples could be sorted, polished, and sized with negligible losses from bruising.

Additional developmental work underway includes a filling device for putting sorted and sized apples into pallet boxes rapidly and gently, and with a full, even fill of apples.

These studies are directed toward providing a means whereby apples can be economically pregraded, presized, and stored in pallet boxes for future packing.

Trade names and the names of commercial companies are used in this publication solely to provide specific information. Mention of a trade name or manufacturer does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

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A UNITIZED BRUSH GRADER-SIZER FOR APPLES

By Stanley W. Burt and Glenn O. Patchen[1]

SUMMARY

This report describes the development, operation, and testing of a new, unitized, apple brush grader-sizer. This brush grader-sizer was designed to: Eliminate most of the drops and transfers that fruit must sustain with existing graders; carry fruit along on a soft nonbruising surface; and reduce fruit bumping together or hitting against the equipment. Preliminary trials suggested that the development of a brush-bed concept would permit adequate sorting, brushing, and sizing, and at the same time provide very gentle handling.

A full-scale operating model of the brush grader-sizer, together with a return-flow belt packing system, was built and installed in a commercial packinghouse. The grader provided for separating apples into Extra Fancy, Fancy, Processor, and Cull grades. The first two grades were divided into six size groups and delivered to return-flow belts. The last two grades (small fruit and culls) were run into pallet boxes for further disposition.

Tests conducted while the brush grader-sizer was in full-scale commercial use showed that for sorting, the machine was probably superior to existing equipment. For brushing or polishing, it was adequate. For sizing however, it was less accurate than had been anticipated from preliminary tests. Packers were able to select sizes from the return-flow belt with accuracy, but their packing rate was slower because of their added responsibility for sizing the fruit. The only bruising to fruit with the brush grader-sizer occurred in transferring apples and dropping them down from the sizing section to takeaway belts. There, bruising occurred only in a small portion of the large fruit.

The costs of owning and operating the brush grader-sizer are approximately the same as for existing graders. The primary advantage of the unit is its gentle handling of fruit, which will become even more important with pregrading operations. Also, if pregrading before storage becomes a standard operation, group sizing will probably be adequate.

INTRODUCTION

Existing grading and sizing equipment has been refined to the point where probably only minor improvements are now possible. When grading and sizing equipment is properly maintained and accurately adjusted, it performs well. It is, however, subject to certain built-in limitations. One of these limitations is the machine's several individual components, which are placed in a sequence, and require fruit to sustain several transfers and drops while being passed from one component to another. These transfers and drops can bruise the apples. Another limitation is that most grading and sizing equipment depends on the rolling action of fruit for most of its progression through the machine. Transferring apples from one piece of equipment to another by rolling, subjects them to possible bruising; because they are not perfect spheres, they roll irregularly.

The unitized brush grader-sizer is a single unit that incorporates the functions of sorting, brushing, and sizing of fruit. In designing the new machine, the major objectives were to (1) minimize the amount of bruising by eliminating the number of individual components in existing equipment; (2) rotate apples so they could be viewed more easily during sorting; (3) provide the necessary brushing and polishing; and (4) provide for accurate grading and sizing. Also, the new brush grader-sizer would need to maintain a production volume that is at least equal to existing graders. It would have to be mechanically dependable, easy to maintain, and economical in ownership and operating costs. If these objectives could be achieved with the brush grader-sizer, some disadvantages of existing equipment would be overcome.

DEVELOPMENT OF THE BRUSH GRADER-SIZER

The unitized brush grader-sizer is a new concept in fruit grading and sizing. Several brushes, in a parallel and closely spaced series, translate and rotate at preset rates, and provide a bed of brushes on which apples rest while being sorted, brushed, and sized. Figure 1 shows this in a schematic view. The objective of a single, integrated unit, without fruit transfers, would be realized

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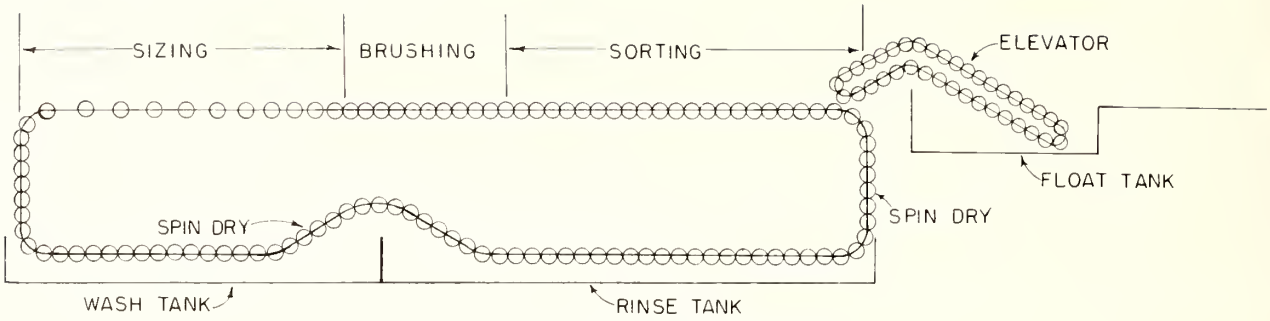

FIGURE 1.—Side view of brush grader-sizer.

by providing translation of the brush bed, plus independent control of brush rotational rates in the individual sorting, brushing, and sizing sections.

To minimize bruising, a new letdown mechanism was designed to receive apples as they dropped through the brushes at the time of sizing. This letdown mechanism was incorporated into the machine to reduce the fall distance of fruit and the incidences of apples striking each other when they are mechanically sized. The machine had the capacity of sizing two grades of fruit simultaneously.

With the objective established and the basic design conceived, a mockup brush grader-sizer was constructed. The mockup model consisted of two short lengths of brushes mounted parallel in a frame. The brushes could be rotated at different rates. Also, the space between the brushes could be varied by moving one brush away from the other. With this mockup, it was possible to determine the bruising that occurred when apples were dropped onto brushes and to estimate the accuracy of the sizing method. Results of these tests warranted the construction and testing of a prototype.

A prototype unitized brush grader-sizer was built and installed in a commercial packinghouse. A complete description was reported earlier.[2] This report covers modifications that were made on the brush grader-sizer and the results of test runs.

OPERATION OF THE BRUSH GRADER-SIZER

The brush grading-sizing operation consisted of delivering apples to the grader-sizer, sorting, brushing, sizing, and packing the apples. These operations are separate, but closely interrelated; what affects one operation affects each of them. Therefore, each operation of the brush grader-sizer will be considered separately, and then together, as a complete grading operation.

Delivery of Fruit to the Brush Grader-Sizer

The purpose of the delivery system was to get apples from a pallet box onto the surface of the brush grader-sizer. A conventional dumper and float tank were used, but an elevator was designed specifically for use with the brush grader-sizer. In the original elevator design, apples were lifted from the float tank by a series of large polyurethane rollers. Apples were carried up out of the tank between two rollers and back down to a position just above the brushes, where they were released and dropped into the space between two brushes at the head of the sorting section.

Soft polyurethane rollers were used to protect the fruit from bruising and to absorb water from the surface of apples. In practice, however, the polyurethane rollers tended to hold apples past their release point and absorbed only an insignificant amount of water from the fruit. Therefore, the polyurethane rollers were replaced with conventional, smaller-diameter, rubber-covered rollers. Pusherbars were added at the end of the elevator where the fruit left the elevator and dropped onto brushes. These pusherbars assured that all apples were released from the elevator at the same time, and that all apples in a row arrived at the brushes at the same time (fig. 2).

The movement of the elevator and brushes was synchronized so that fruit dropped into the spaces between brushes rather than onto brushes. When an apple landed on top of a brush it could be damaged; however, when it landed between brushes, the brush fibers broke its fall and no measurable bruising occurred at this transfer point. The elevator and brushes were synchronized by coupling the elevator to the brush-drive mechanism through a chain and sprocket arrangement. The pusherbars assured that all the apples in a row—regardless of size—left the row together. A hump in the elevator brought apples as near as possible to the brushes before releasing them, so that their fall distance at this point was never greater than 6 inches. Fruit was restricted from the middle 8 inches of the elevator. Even so, the remaining 20 inches on both sides of the elevator delivered five or six apples each per row to the brushes, a total of 10 to 12 apples, every time two brushes came into position to receive a row of apples from the elevator.

Sorting

The sorting section of the brush grader-sizer is shown in figure 3. Overhead belts carried off the two lower grades of apples, and culls were put down chutes located

[2] BURT, STANLEY W., and PATCHEN, GLENN O. GRADING AND SIZING APPLES WITH BRUSHES. U.S. Dept. Agr., Agr. Res. Serv. ARS 52-18, 14 pp. 1966.

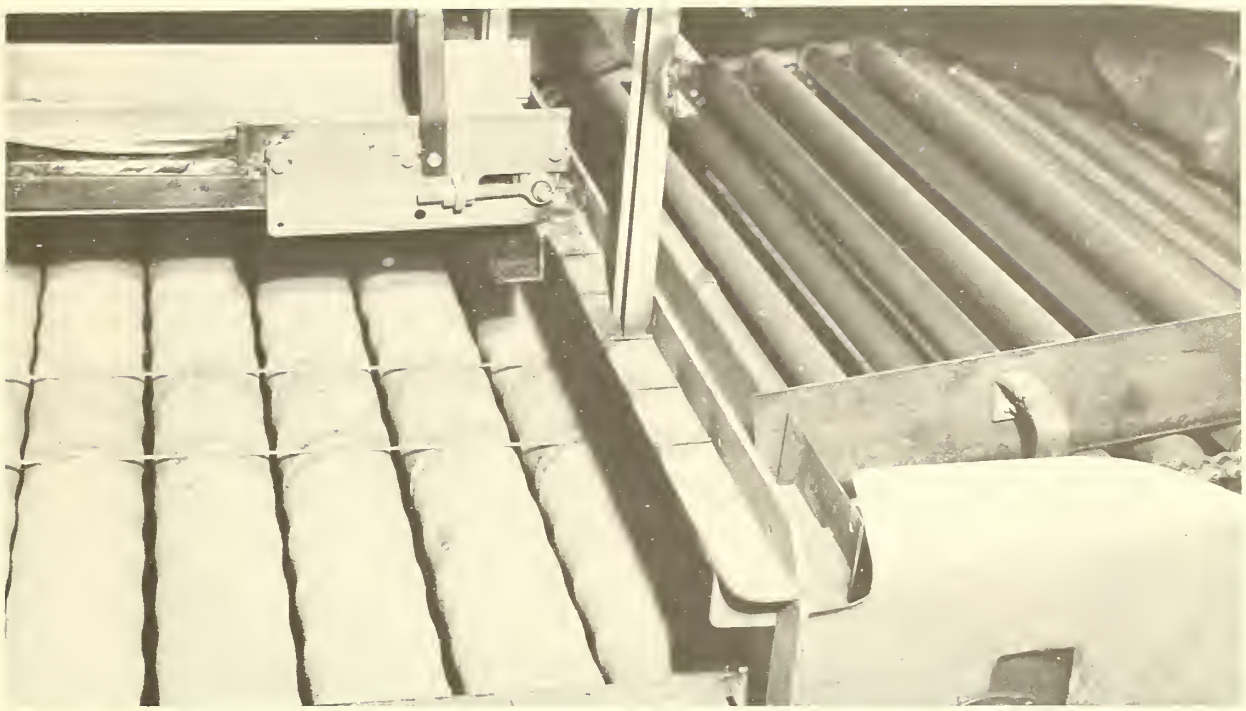

FIGURE 2.—Elevator rolls (right) lifted apples from float tank and released them above brushes (left).

alongside each sorting station. First grade apples were left on the brushes, and second grade apples were placed in the center section of the brushes.

With the brush grader-sizer, apples did not roll randomly the length of the sorting table as they do with existing graders. Instead, when apples were delivered from the elevator to their place between two brushes, they occupied that same space until they were either removed by a sorter or sized out. Because apples did not roll, they did not bunch up or rub against other apples. Instead, they passed before the sorters in rows of five or six apples per row. The rows were 5¼ inches apart. By rotating the brushes, the apples were rotated, and sorters were able to see most of the fruit's surface.

The original design included 10 sorting lanes—5 on each side—which were formed by ropes 5 inches apart, stretching the length of the sorting section. Each sorter was assigned a lane, and was responsible for grading all the fruit in his lane. The ropes were removed, however, when it became impossible to prevent apples from striking them as the fruit dropped from the elevator. Further effort to provide lane sorting was made by trimming the brushes to form indentations or cups (figs. 2 and 3). When the machine was in operation, most apples would stay in their cups. However, the small percentage that would not, as well as a sorter's inclination to sort over the whole table, led to abandoning lane sorting.

Translation of the brushes was provided by a 3-horsepower, variable-speed motor driving a chain which pulled the brushes through sorting, brushing, and sizing. Brushes were rotated in the sorting section by a 2-horsepower, variable-speed motor driving V-belts which rotated pulleys at the ends of the shafts. Alternate brushes had pulleys at opposite ends, so that a V-belt was required on each side of the sorting section. This pulley arrangement made it possible to either rotate all brushes at the same rate or alternate brushes at different rates. These V-belts controlled brush rotation from a point ahead of the place apples dropped onto the brushes to a point immediately ahead of the polishing section.

Because brush rollers in the sizing section had to move apart, a direct linkage between brush rollers could not be used. Instead, at each end of each brush shaft was a flanged block collar linked by roller chain to a set of steel wheels riding in a C-channel directly below the collar (fig. 4). These wheels rode on either side of the chain, and were held in place by a pin through an

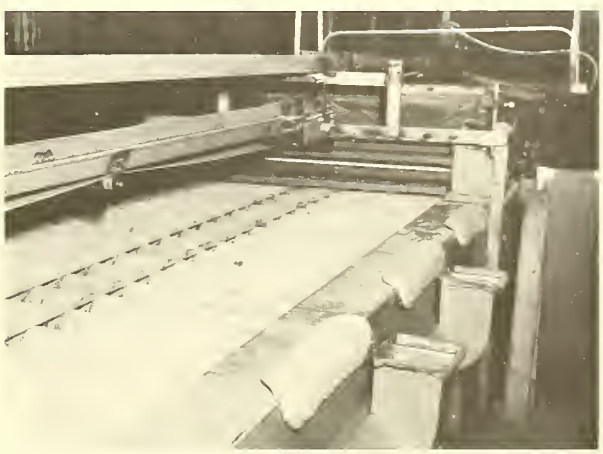

FIGURE 3.—Sorting section of brush grader-sizer (foreground), with elevator (background), lane for second grade fruit (center), belts for lesser grades (over brushes), and cull chutes (next to sorting stations).

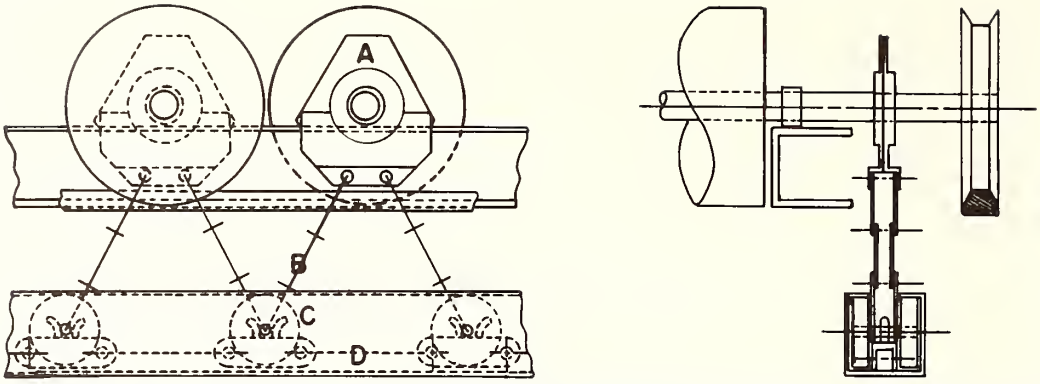

FIGURE 4.—Drive linkage in sorting section showing relationship of flanged block collar (*A*), roller chains (*B*), steel wheels in C-channel (*C*), and helper chain (*D*).

attachment link. The wheels in turn were connected to the collar of the adjoining brush by a roller chain.

The space between the channel and the brush shafts determined the distance between brushes. In the sorting section, this spacing was at its maximum so that brushes were as close together as possible without their fibers touching. Originally, in this proximity, the roller chains tended to pull in a straight line and consequently bound up and locked. To prevent locking, a helper roller chain, synchronized to match the translation speed of the brushes, was installed to travel along the bottom of each of the C-channels. These chains carried sets of lugs spaced 5¼ inches on center, the same spacing as the wheels in the channels. As each set of wheels entered its channel at the head of the sorting section, lugs on the helper chains moved into place with it so as to cradle the pin that held the wheels to the attachment link. Because the helper chains moved at the same rate as the main drive chains, tension on the roller chains connecting the wheels and brush collars was lessened, and the brushes moved ahead freely.

At the beginning of the brushing section, the helper chains were carried down out of the channels by a sprocket on each side. From this point until brushes completed the cycle and returned to the head of the sorting section, translation was provided by the connecting links riding over sprockets at the end of the machine. The sprockets, one on each side of the machine, were on a common shaft. This shaft was powered by the main drive chain.

Shields were installed over all moving mechanical parts for workers' safety. These shields could be easily removed for necessary maintenance work. A piece of sheet metal was positioned directly under the brushes on each side in the sorting section and sloped toward the center of the line, which was left open. Leaves and trash that fell between brushes accumulated on these sheets. At the end of the day, this material was removed by inserting a scraper bar between two brushes and pushing it toward the center. Trash fell through the open center area for collection and disposal.

Brushing

The amount of brushing or polishing that apples should receive has not been established. Length of time they should spend on a brushing unit and the optimum rotational rates of the brushes vary with variety, condition, and previous treatment of the fruit. Any evaluation of brushing is largely subjective because the only result that can be measured is the amount of gloss on the surface of the apple. One objective measurement, a negative one, is the amount of damage that fruit suffers during the brushing process.

The time apples stayed in the brushing section was determined by the length of the brushing section and the rate of translation of the brushes. Because fruit was brushed during the entire time it was on the grader, the section devoted solely to brushing was set at only 4 feet. At a normal translation rate of 32 feet per minute (ft/min), each apple would be brushed 7.5 seconds. Over this 4-foot section it was possible to rotate alternate brushes from 0 to 200 revolutions per minute. Rotation was maintained by two variable-speed motors driving V-belts across the pulleys on the brush shafts. These V-belts were overhead and engaged the pulleys immediately after they were released from the V-belts controlling brush rotation in the sorting section. The two variable-speed motors were mounted on frames directly over the brushing section. These are shown in figure 5, which also shows the position of the brushing section relative to the rest of the grader.

Brushes were pulled through the brushing section in the same manner as they were pulled through the sorting section, except that in the last 12 inches there was no helper chain in the bottom of the channel.

Sizing

At the point where the helper chain left the channel, the channel began to incline causing the space between brushes to widen. The rate of incline was such that, in the space of one linear foot, the gap between brushes increased from ¼ inch to 1½ inches. Having achieved this space between brushes, the rate of incline of the channel was reduced to effect a rate of spread of ⅛ inch per foot of brush travel. The sizing section began here.

Separation of apples into their respective sizes posed some serious design problems. The brushes had to separate at a steady, uniform rate. Positive rotation had to be maintained whatever the brush loading, and a

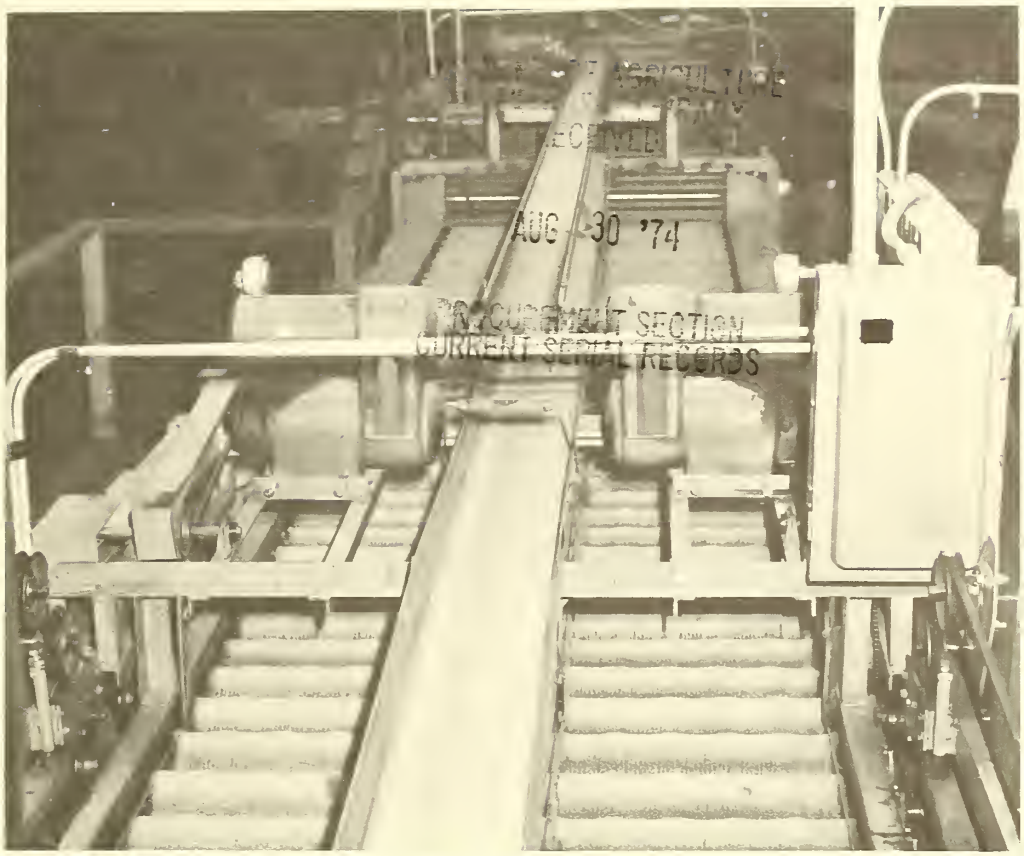
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FIGURE 5.—Separate variable-speed drive motors (left and right) for rotating alternate brushes at different rotational rates in the brushing section (center), sorting section (background), and sizing section (foreground).

minimum-bruising letdown arrangement for transferring apples to takeaway belts was necessary.

Eleven feet of the grader was devoted to sizing. As soon as brushes left the brushing section, they began to separate and continued to do so until reaching the end of the sizing section. Over this section, the space between brushes increased from 1½ to 2¾ inches. This separation was achieved by inclining the channel in which the steel wheels rode. Figure 6 shows the brushes beginning to separate. As brushes moved ahead and separated, a point was reached where the weight of an apple overcame the resistance of the brush fibers supporting it and that apple dropped through between the brushes. The place where it dropped through the brushes determined its size.

Under the brushes was a set of letdowns for guiding and cushioning apples after they left the brushes until they rolled down onto the takeaway belts. The original design called for eight separations. This was later reduced to six when it was determined that more room was needed for each group to prevent fruit from bridging and piling up in the letdowns.

A letdown was divided into three parts: One part delivered first grade apples from the right side of the sizing section to a takeaway belt; another delivered first-grade apples from the left side to a different takeaway belt; and the third part delivered second grade fruit to a center takeaway belt. Because apples from each side of the sizing section were delivered to separate takeaway belts, the common problem of apples dropping onto previously sized apples was largely eliminated. All letdown surfaces that came in contact with fruit were padded with ¼ inch polyurethane. Takeaway belts moved at 65 ft/min. At this rate, apples were removed from under the sizer fast enough to prevent their piling up or jamming. Figure 7 shows the letdowns with the brushes removed.

While the rate of brush rotation, and consequently the rate of apple rotation, affected the sizing that took place, the need for steady, constant, and unvarying rotation was even more important. Otherwise, a row of apples could be drawn through prematurely when the brush which held up the fruit slowed, even momentarily, and the adjacent holding down brush became dominant.

When brushes left the sizing section, they travelled at maximum spacing along the bottom side of the grader. Upon reaching the beginning of the sorting section, the brushes again closed up to minimum spacing (fig. 8).

Brushes were rotated by overhead V-belts riding in pulleys mounted on the brush shafts. Since the V-belts had only point contact with the pulleys, it was necessary that V-belts be held down snugly to prevent belt slippage. This was done with a row of hard rubber wheels spaced close together in a channel which was spring-mounted to the grader frame. These wheels ran the length of the sizing section and were located directly over the V-belts.

By increasing compression on the springs, the wheels would press down on the V-belt, forcing it tighter into the pulley and assuring its rotation (fig. 9). If the springs were compressed too much, the brush could lock up and not rotate at all. Consequently, there was only a small difference between too much and too little compression, and close adjustment at this point was necessary.

Packing

Once apples are sorted, brushed, and sized, the last step in the grading procedure is to put them into containers for shipment.

Many packing systems are in use, and the system used is not dependent on the grader. The return-flow belt accumulating system was chosen for use with the experimental brush grader-sizer. Distributor belts were needed because of the short distance within which sizing was done. These belts could be mounted on the same frame and driven by the same drives as the packing belts. Also, return-flow belts offered a certain flexibility of operation. By moving shunts, the packing area assigned to different sizes could be changed; or by removing shunts, sizes could be combined. A layout of the packing system, using the brush grader-sizer, is shown in figure 10.

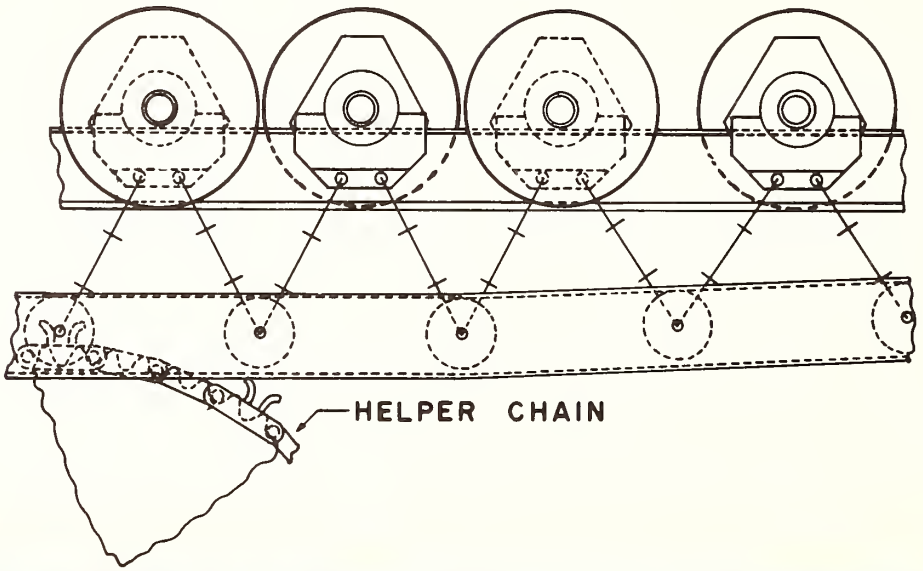

FIGURE 6.—Drawing of drive linkage at point where gap between brushes begins to increase. Note helper chain leaving C-channel.

FIGURE 7.—Overhead view of letdown system (located directly under brushes in sizing section) showing sloping ramps and well padded surfaces. Brushes were removed for the photograph.

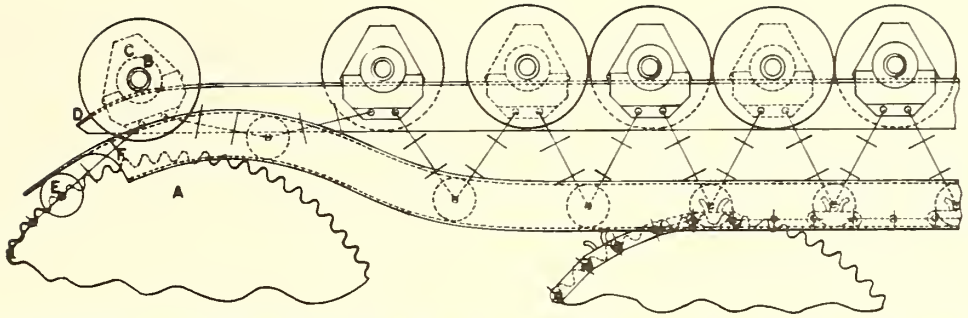

FIGURE 8.—Drawing showing how brushes are brought from maximum to minimum space at head of sorting section. Idler sprocket (*A*) positions bearing (*B*) in flanged block collar (*C*) to ride on top of rail (*D*) and steel wheels (*E*) to enter C-channel (*F*). As space between *D* and *F* increases, brushes are pulled together.

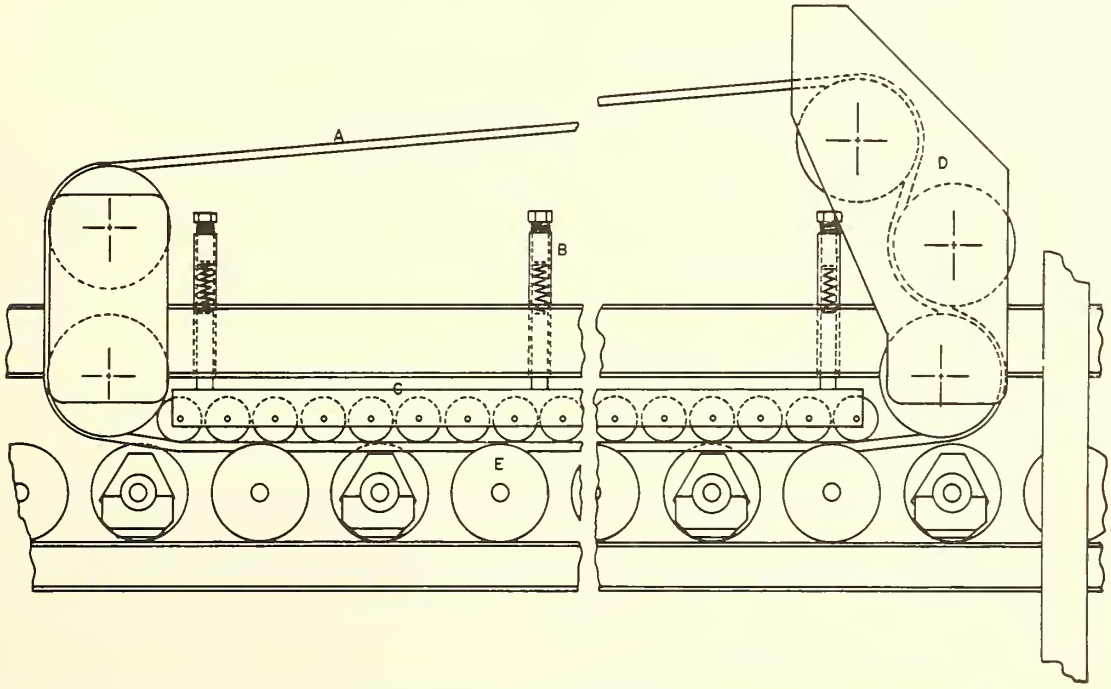

FIGURE 9.—Drawing of V-belt and holddown device over sizing section. Uniform pressure was essential to maintain constant rotational rate during sizing. *A*, Overhead V-belt; *B*, spring holddown; *C*, hard rubber wheels; *D*, V-belt tightener; and *E*, brush pulley.

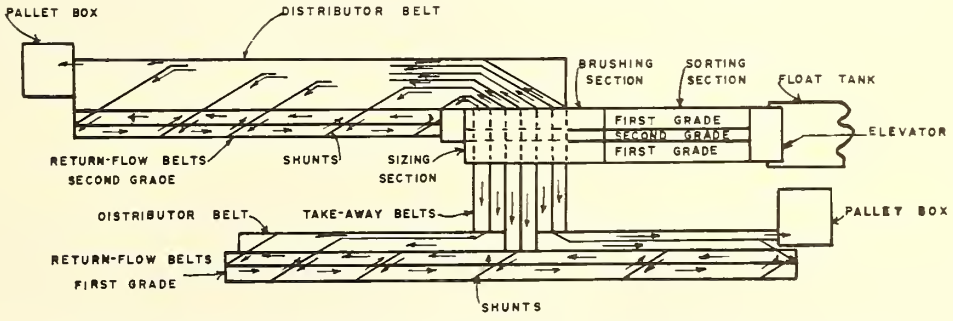

FIGURE 10.—Diagram of packing system layout that employed the brush grader-sizer.

Takeaway belts connected the brush grader-sizer with the packing system. These belts were 8 inches wide, traveled at 65 ft/min, and delivered fruit to distributor belts. The same basic system was used for both the first and second grade fruit. However, to achieve fuller utilization of floorspace, it was necessary to incorporate differences into the two systems.

Packing First Grade Fruit

Of six size groups delivered from the sizer, the two middle sizes travelled directly to the return-flow belt, but the two smaller and two larger size groups of apples travelled from a takeaway belt to a distributor belt and then to the return-flow belt. The two 18-inch-wide distributor belts travelled in opposite directions at a rate of 40 ft/min, and each belt was divided into two lanes—a separate lane for each size group.

A nonmovable shunt kept the two middle size groups of apples separated at the point in the machine where these apples left the takeaway belts and entered onto the return-flow belt. The largest apples rode to the end of the distributor belt where they were shunted across to the return-flow belt. The second largest apples were shunted to the return-flow belt at a point between the center and end shunts. This system of shunting fruit from the distributor belt to the return-flow belt was also used for the two smaller size apples except that the smallest size apples were carried off the end of the distributor belt and collected in a pallet box.

To determine the relative effectiveness of powered and nonpowered shunts, both types were used. A powered shunt consisted of a 3-inch-wide, single-ply, flat belt which travelled over pulleys at both ends of the shunt. The belt rode against a sheet metal backing which prevented the belt from collapsing from the pressure of apples against it. The nonpowered shunt was a 4-inch-wide board that was faced with thin-gage sheet metal and a strip of Teflon tape on the surface where the greatest contact occurred.

The shunts were moved easily, except for those at each end and in the center, so that the area of return-flow belt allotted to a particular size group could be enlarged or narrowed as the size requirements changed.

Packers, with their regular packing stands, were stationed alongside the outer return-flow belt facing oncoming fruit. The number of packers varied, but there were usually six to eight packers per line. As fruit passed in front of the packers, they would reach over the belt, pick up an apple, wrap it, and deposit it in a tray pocket; all these actions were performed in one coordinated movement. When a tray was filled, the worker placed an empty tray in the carton and continued packing. When a carton was filled, the packer removed it to a chain conveyor, returned to the packing area, placed an empty carton on the packing stand, and continued packing.

Packing Second Grade Fruit

All second grade apples were delivered from the sizer to a distributor belt. This belt was 48 inches wide, travelled at 40 ft/min and was divided into six lanes—a separate lane for each size group. The smallest apples rode in the outside lane and had to shunt across the entire width of the distributor belt to get into their lane. Larger apples, coming out at the end of the sizer, were in their lane as soon as they rolled off the takeaway belt (fig. 11).

Lane formers extended only 4 feet past the end of the sizer. By the time they reached the end of the lane formers, apples had stopped rolling, and did not change their positions on the distributor belt until encountering the shunt, which directed them to a section of the return-

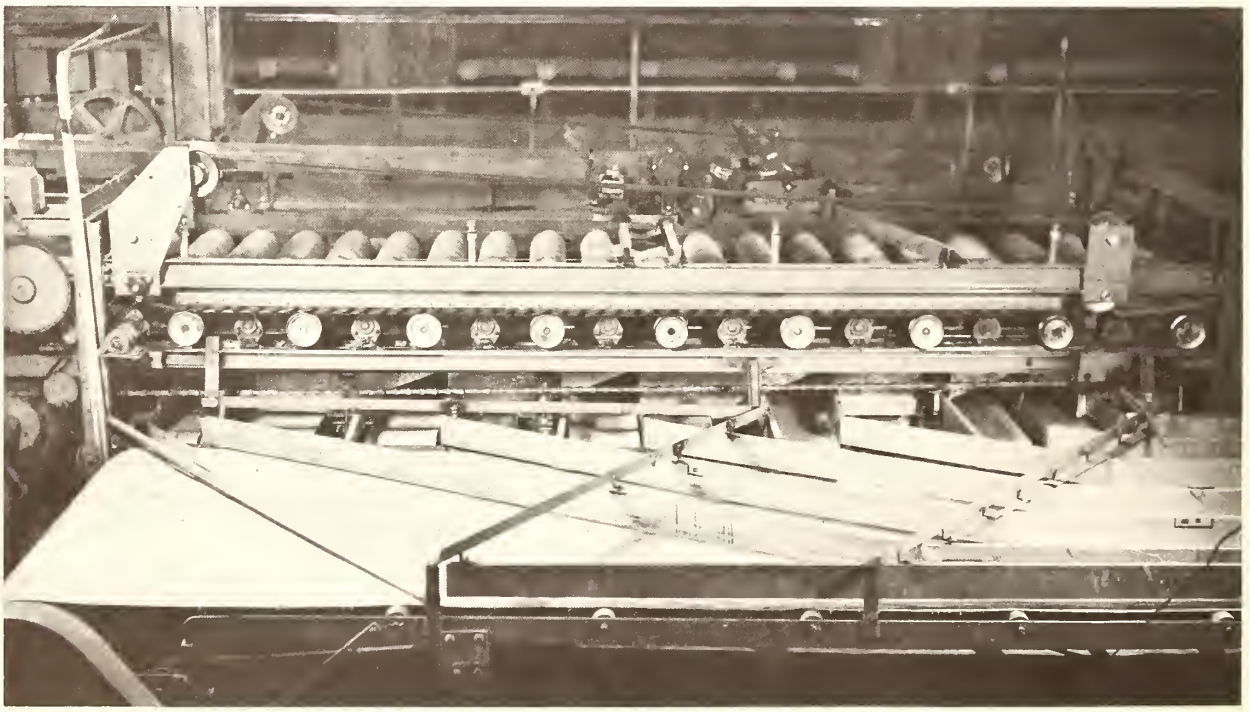

FIGURE 11.—Second grade distributor belt with lanes for keeping sizes separated.

flow belt. Small apples were carried off the end of the distributor belt and collected in a pallet box; the largest apples were shunted onto a table. Only the four middle size groups transferred onto the return-flow belt.

Apples were transferred from the distributor belt to the return-flow belts by nonpowered shunts. These same shunts transferred fruit from one return-flow belt to the other until the fruit was packed. These aluminum shunts were lightweight, movable, strong, and effective.

Packing procedure was the same as with first grade fruit. Packers stood alongside the outside return-flow belt, removed apples, wrapped them, and placed them in trays. Fewer packers were required than with the first grade apples, since there were fewer second grade apples. With both grades, the inside return-flow belt was 12 inches wide and travelled 40 ft/min. The outside belt was 18 inches wide and travelled 20 ft/min. This was the best speed for packers to observe approaching apples and to pick them from the belt for packing.

EVALUATION OF THE BRUSH GRADER-SIZER

The primary objective of the brush grader-sizer was to provide an economical and efficient means of grading apples with a minimum amount of damage to the fruit while maintaining the essential volume of production. In the final analysis, comparisons must be made on the basis of dollar costs. Some of the cost evaluations are direct and easy to obtain. Other values are less tangible and more difficult to determine, such as the value of improved sorting performance or of better sizing.

All handling of fruit before sorting (for example, dumping, treating, and removal from the float tank) was by standard procedure and not included in the brush grader-sizer study. The new equipment began at that point where apples were deposited initially on brushes for sorting.

Sorting

Sorting is a key operation that usually sets the rate at which the total operation proceeds. It must be done well since grade requirements allow for few errors. A packinghouse that packs at the bottom of a grade soon becomes known in the marketplace and is distinguished from one which consistently packs at the top of the grade.

When a row of apples was released from the elevator, the fruit dropped into the trough between two brushes. Apples did not roll, nor were they pushed by other apples. Their entry onto the brush grader-sizer was not random, but mechanically controlled so that every time a trough between two brushes was in position, a row of apples would leave the elevator and descend onto the brushes.

This arrangement assured that: (1) Apples would not come in contact with each other while being transferred from the elevator to the sorter; (2) no bruising occurred at this point because each apple dropped onto a bed of polyethylene fibers which absorbed the force of its fall; and (3) apples would pass by the sorters in rows 5¼ inches apart. Cups in the brushes tended to prevent apples moving laterally, so that, in effect, they were in lanes when inspected by the sorters.

Apples rode high on the brushes and rotated in the forward direction, giving sorters an excellent view of the apple. Because Delicious variety apples tend to rotate about the stem-calyx axis, the part of the apple away from the sorter was out of view. This shortcoming is typical of most sorting tables. Sometimes apples turned over so that the hidden end could be seen, but most did not.

Generally, workers commented favorably on this sorting system. Sorting performance is largely the result of several variables, such as the number of sorters and their experience, the quality of fruit being sorted, the number of grades being sorted, and the rate at which fruit passes before sorters. Any and all of these variables can change during a sorting operation. However, because of the manner in which fruit is presented, controls over the rates of translation and rotation, and the personal reaction of sorters, the sorting part of the brush grader-sizer was probably superior to most existing sorting tables.

Brushing

Because apples were carried on brushes, they were being brushed from the time they entered onto the grader-sizer until they were sized out. The question was: Would the amount of brushing or polishing that apples received during sorting and sizing be adequate? Examination of the fruit indicated that it made no difference what rotational rates were used in the brushing section, so long as the rates were not so high as to burn the fruit. However, apples appeared to have received ample polishing while they were being sorted and sized, making a separate section just for brushing unnecessary.

Sizing

Dividing apples into size groups is a critical part of the grading operation. Today's market requires that apples be sized within closely defined tolerances. Apples are packed according to precise size requirements and, if the fruit is not properly sized by the grader, it must be checked for size by the packer, or the wrong size fruit is packed into cartons.

The brush grader-sizer provided for six size categories: (1) Size 180 and smaller; (2) size 163 to 150; (3) size 138 to 125; (4) size 113 to 100; (5) size 88 to 80; and (6) size 72 and larger. While the unit did separate small, medium, and large fruit, the sizing performance of the brush grader-sizer did not match the promise of the earlier mockup. Almost all sizing errors with the brush grader-sizer were due to its classifying apples larger than they really were. These errors are listed in the following tabulation:

	Percent
No sizing error	46
Undersized one size	6
Undersized two sizes	1
Oversized one size	42
Oversized two sizes	5
Total	100

Because the sizing errors were mainly in one direction, it is possible that further investigation would reveal the reason for this and that the number of sizing errors could be reduced. For example, many apples did not stay in the deep part of the brush cups, but rode up on the edge or even on the peak between cups. Apples that did this were carried beyond the point where they should have dropped out, and subsequently they dropped onto a takeaway belt meant for larger size apples.

Packing

Packing was done from return-flow belts. Extra Fancy and Fancy grade apples were packed simultaneously but from separate belts. The same packing method was used for both grades, although the volume of fruit in each grade was different.

Originally, the return-flow belts were divided into six sections—one for each size group. These six sections were reduced to four sections when it became apparent that the volume of the smallest and the largest size groups did not warrant belt space. These two size groups were collected on tables at the ends of the distributor belts. Even so, the mixture of sizes in each section required that packers do their own sizing as they packed. Consequently, all shunts, except those at the ends, were removed, and no attempt was made to separate sizes on either return-flow belt. Thus, packers were presented with everything from size 163 to size 80, and from this mixture they selected the sizes they were to pack.

Doing their own sizing was a new practice for the packers, as was packing from a return-flow belt. At first, the workers were uncertain of themselves and unsure of the procedure to follow. Their productivity was low, and cartons often had to be repacked because of improper weight. However, as the packers gained experience they became more adept at selecting sizes. Productivity increased and repacking was almost eliminated.

As with any packing system, there was a wide range in the productivity of individual packers. In tests, only Golden Delicious apples were packed, and all of these were wrapped and placed in trays. The average packer produced 95 cartons per day (7½ working hours), or one every 4.7 minutes. Faster workers packed up to 120 cartons per day, or one every 3.8 minutes. Because they were paid on a piece rate, each packer was given a chance to pack all the different sizes during the day. This required the packer to be familiar with all the sizes. If it were possible for packers to be confined to packing only one or two (or at the most three) sizes, they could become expert in these few sizes and might thereby increase their productivity. Since there are different labor requirements for packing each size, an adjustment in pay rate would have to be made for each size.

If, for example, size 113 was taken to be the mean size and the size on which the packing pay rate was based, then the base pay rate (based on size 113) would be multiplied by the adjustment factors shown where apples were tray packed:

Size	*Adjustment factor*
80	0.80
88	.85
100	.92
113	1.00
125	1.06
138	1.13
150	1.18

Bruising

There is no way to completely eliminate apple bruising; some apples bruise while in storage. All that can be hoped for is to control the amount and severity of bruising that apples sustain during handling and grading operations. Any bruising that apples incur lowers their value, so it is important to know in what way and to what degree a new method or new equipment item may damage fruit.

The brush grader-sizer was tested in two parts with Golden Delicious apples. One part involved sorting, brushing sizing, and the other the return-flow belt packing system:

Treatment[1]	*Indentations per apple*
Apples circulated on return-flow belt for 3½ minutes and 4 revolutions[2].	0
Apples circulated on return-flow belt for 7 minutes and 8 revolutions[2].	0
Apples placed in float tank, transported up elevator, dropped onto brushes, carried through sorting and brushing sections, slipped through brushes in sizing, and recovered on return-flow belt. One revolution only.	.1[3]

[1]At time of treatment, apples pressure-tested 10.5 pounds. At time apples were examined, they pressure-tested only 8.8 pounds, but were not shrivelled.

[2]About one-half the belt surface was covered with apples.

[3]These indentations were nearly all shallow and not discolored and would not have affected the grade of the fruit. The few that would have lowered the grade were all on large fruit and occurred in the letdown.

Seldom will such soft fruit be run on any grader, but fruit pressure-testing 10.5 pounds (although still turgid) was chosen so that the grader-sizer would be tested under adverse conditions. Had the fruit been firmer, it is possible that no bruising would have been detected. Some bruising was expected from apples shunted from one belt to another, but surprisingly none occurred at this point.

Production

Productive capacity of the brush grader-sizer is subject to the same limitations as other existing graders. The distance that a sorter can reach determines the width of the sorting table; the size of the apple determines the number in each row; the ability of the sorter to see the apples clearly determines the maximum translation rate; and the actual translation rate at which sorters can perform their task is determined by the quality of incoming fruit.

Sorting tables are normally run at about 32 ft/min. At this rate, with 10 apples per row and the rows 5¼ inches apart, the grader has a cpacity of 43,890 apples, or the equivalent of 400 cartons per hour. This number would be reduced by the number of culls (processor fruit) that are removed, by any delays that take place, and by changes in quality of orchard-run fruit that may permit speeding up or require slowing down the grader.

If the incoming fruit is of particularly high quality, the sorters can handle more apples and a larger percentage of the fruit is delivered to the packers. When this happens,

it may be that packers will be overloaded, and the packing rate then sets the pace. This situation could be alleviated by lengthening the return-flow belt, by providing more tubs or tables for accumulating fruit, or by increasing the number of packers. However, this solution is not practical once packing equipment is installed. In practice, when packers are overloaded, the entire grading line is slowed down.

The return-flow belt for the first grade apples was 60 feet long and provided room for 10 packers. The second grade belt was 40 feet long with room for six packers. These packers were rarely able to pack at a rate to match the full capacity of the brush grader-sizer.

Cost

Costs associated with a fruit grading line fall into four primary categories: Ownership, operation, labor, and damaged fruit. Ownership and operating costs for the brush grader-sizer are shown in table 1.

Ownership and operating costs approximate those for existing grading and packing systems. The costs of the brush grader-sizer must be estimated, since only a prototype model has been produced and actual production costs are not known. While mechanical dependability appeared to be one of the brush grader's better features, maintenance costs are greater than they would be for conventional equipment which has been thoroughly developed and tested.

Brushes are a costly part of the brush grader-sizer, and their lifespan can only be determined by experience. But since all the brushes undergo the same usage, their wear should be uniform. Also, turning brushes at a high rotational rate on their return cycle relieves them of much of the dirt and water that would otherwise accumulate on and between the brush bristles. Dirt accumulation causes the greatest wear on brushes. The life of brushes on the brush grader-sizer is expected to be years beyond that of brushes as they are currently used.

Operating costs are based on the rated capacity of the following motors:

Motors	*Horsepower*
1 main drive	3
2 vari-speed	2
2 vari-speed	1
1 takeaway belt	¾
4 belt-drive	1
Total converted horsepower	7¾

Power to run the grader represents only 14.5 percent of the operating cost and 1.5 percent of total annual cost. The operational cost is the least expensive individual cost item.

Because the brush grader-sizer required the same amount of labor per operation as conventional equipment, and because there was no change in the basic nature of these operations, no change in the amount of labor required by adopting the brush grader-sizer was anticipated.

The same number of sorters were required with both machines. With the brush grader-sizer, apples were presented to sorters in such a way as to make their work easier, but the number of sorters was still determined by the volume and the quantity of apples that must be inspected. However, the other labor utilizing operation, packing, was less productive. Because packers had to size their own fruit, they could not pack as rapidly as they could when they were not responsible for sizing. The difference in their output would undoubtedly have decreased as the packers gained experience; however, the output of the packer on the unitized brush grader-sizer could not be expected to reach the output of packers who did not have to concern themselves with sizing fruit. On the other hand, the brush grader-sizer did provide a second inspection of each apple and the off-grade fruit that eluded the sorters was usually caught by the packers.

A certain flexibility was inherent in the return-flow belt system, which permitted packers to switch sizes among the fruit being packed. For example, if the run of fruit was predominently size 100, then all or most of the packers could pack this size. They could all determine which sizes were on the belt and could pack accordingly.

TABLE 1.—*Estimated ownership and operating costs of brush grader-sizer with return-flow belt packing system*[1]

Equipment item	Initial cost	Expected life	Ownership costs				Operating costs			
			Depreciation	Interest[2]	Insurance and taxes at 4 percent	Total	Power[3]	Maintenance	Total	Total annual cost
	Dollars	*Years*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Brush grader-sizer	30,000	10	3,000	900	1,200	5,100	72	500	572	5,672
Return-flow belt system	5,000	10	500	150	200	850	30	100	130	980
Total	35,000	10	3,500	1,050	1,400	5,950	102	600	702	6,652

[1]Based on 1,000 hours annual use.
[2]Computed at 6 percent of average investment.
[3]Based on 1 cent per kilowatt hour.

The two benefits of the brush grader-sizer—a second sorting and packer flexibility—are difficult to evaluate and reduce to a dollar figure; however, they do offset, to some degree, the reduced packing rate that occurred because of the mixed sizes on the return-flow belt system. The primary purpose of the brush grader-sizer was to provide a system that would permit sorting, brushing, and sizing with a minimum amount of bruising. So far as this objective was concerned, the grader was successful. The only discernible bruising occurred to some of the very large fruit, which constituted only a small part of the apples packed.

A 1-percent reduction in the number of apples bruised represents a saving of 2,000 cartons of a 200,000-carton total volume. At a price of $5 per carton, this represents a saving of $10,000. But the biggest cost from bruising during grading is probably less direct. Apples bruised during grading are packed out and sold. When these apples are displayed in retail stores their bruises become apparent. Because these bruised apples will be left in the display after the unbruised ones have been sold, the cost of growing, storing, grading, and marketing the bruised apples must be absorbed by those that were unbruised and salable. This raises the price of unbruised apples which in turn reduces the volume sold according to elasticity of demand for apples—a substantial, though less direct, cost.

The costs associated with the brush grader-sizer can be summarized as follows: Ownership and operating costs were approximately the same as for existing graders; labor would increase because of the inexperience of packers who were slower because they had to do their own sizing; and fruit damage would be reduced because of the fewer drops and transfers that apples sustained and because of the protective brushes on which fruit travelled.

CONCLUSIONS AND RECOMMENDATIONS

The brush grader-sizer may well have a place in the pregrading of apples before storage. It permits sorting and group sizing of fruit with virtually no bruising. This is the first requirement of a successful pregrading operation. Hydrodumpers and float tanks, already in use, permit the transferring of apples from pallet boxes to the grading line with minimal brusing, and properly designed hydrofillers promise gentle filling of fruit back into pallet boxes. With a practical method of sorting and group sizing, prestorage sorting and sizing become feasible.

When mechanical harvesting of apples for the fresh market is developed, this procedure will make pregrading a necessity. Mechanical harvesting will be nonselective, and the additional cull fruit and trash in each pallet box will require that fruit be sorted before it is put into cold storage. If fruit is sorted for grade, then it should also be sized.

While its greatest usefulness will be in prestorage sorting and sizing, the brush grader-sizer can also be used to sort and size fruit from storage if close sizing is not critical, or if packers can make some size selections.

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